Electric Vehicle Conversion Course

# Overview and History of Electric Vehicles

The electric motor has been around since 1827 when Ányos Jedlik, a Hungarian physicist, began experimenting with devices he called “electromagnetic self-rotors”. These devices were in turn inspired by Michael Faraday who first demonstrated the conversion of electrical energy into mechanical energy through electromagnetism. Although several attempts to develop and commercialise were unsuccessful due to the high cost of zinc for battery electrodes and a lack of electrical distribution (unlike today) electric motors largely remained a novelty until the end of the 1800s.

It should be noted that oil, whilst being in use for heat and fire as well as asphalt for several millennia, was first drilled for in the 1850s and refined into kerosene. Also, steam engines were in common use for nearly 100 years before commercial electric vehicles became available (around 1895). At the turn of the 20th century the popularity of these three technologies was roughly equal, with the exception of electric being popular as ‘city vehicles’ (especially by women) as they didn’t require cranking or time to heat a boiler.

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Wood Motor Vehicle Co. Circa 1900

Ironically it was the invention of the starter motor which were first installed by Cadillac in 1912 and in most combustion engine cars after 1920 that led to the decline of electric vehicles. Another factor was the high energy density of petrol as compared to batteries which is still a major issue today.

Electric vehicles are now becoming increasingly viable as the modern world realises the impact of burning oil o the environment and the need for greater energy efficiency as the demand for energy increases. This demand is not only driven by the increased use of transport by developed world, but also is exacerbated by unrest in the middle east, the increasing demands of China and India and the fear that fossil fuels are on the decline.



Waverley Electric Vehicles – circa 1903

# Facts and Myths

## Electric Vehicles are expensive.

Whilst brand new commercially available electric and hybrid vehicles are expensive in comparison to other cars renovating or converting older vehicles is a cheaper alternative. Depending on where the parts are sourced from conversions cost anything up to around $25,000, a second-hand Prius can be converted to a plug-in for around $5000 to $10000. Restoring an established Electric Vehicle, such as the CIT’s GMC G Van can be as inexpensive as replacing the batteries which in this case was around $4000 (although finding these vehicles can require a bit of searching and luck!). Of course, this is in addition the cost of the vehicle itself which if you’re lucky can be under $5000.

With breakthroughs in electrical energy storage and the rising popularity of Electric Vehicles internationally, the price of commercially available vehicles and components will most likely come down in the future.

Electric Vehicles also have less moving parts and are substantially more efficient and as a result the maintenance and running costs are drastically reduced. Whilst a modern combustion engine car has 100s of moving parts in the engine and gearbox an Electric Vehicle has only one main moving part in the motor, the rotor, and can conceivably do without a gearbox ([http://www.teslamotors.com/own/service](http://www.teslamotors.com/own/service%20) ). The only down side for maintenance is the batteries which need replacing. The interval for this replacement depends mostly on the type of battery, the number of charge/discharge cycles and the depth of discharge. Battery life can also be increased through care and monitoring. In 2010 a Tesla Roadster was driven from Sydney to Canberra on “Green Power” electricity for around $10.

## Electric Vehicles are slow

In fact the opposite is more the case. Electric motors selected for vehicles have higher torque characteristics and a larger range of usable speeds in comparison to combustion engines. The first land speed records were set by Electric Vehicles (<http://www.thrustssc.com/thrustssc/History/Jeantaud.html>) and currently the record for the fastest street legal drag racers in the U.S. and U.K are held by converted Electric Vehicles (<http://www.plasmaboyracing.com/whitezombie.php> & <http://www.caradvice.com.au/122400/electric-volkswagen-beetle-black-current-sets-quarter-mile-record/> ). Also nearly all of the world’s heavy (and sometimes fast) vehicles such as trains and mining trucks are electric or hybrid electric.

## Range anxiety

At present batteries are an issue for Electric Vehicles. Not only is the range limited by the amount that you might wish to spend on batteries but there also comes a point when the increased storage (and perceived range) is negated by their excessive weight. Advances in battery technology (driven primarily by computer and mobile phone technology) have reduced the size, weight and cost of batteries but petrol still has the lead in this area. But the real issue is how far you really need to travel each day. In Australia the average is around 40km a day, a distance that all commercially available vehicles can cover in half a charge or less.

Another factor is the availability of charging stations. This can be easily addressed through a change in habit; for example instead of refuelling once a week (sometimes requiring a detour) Electric Vehicle owners would instead recharge at work and at home.



Tesla X – to be release in the U.S. in 2013

## Lack of Infrastructure

This is really just another part of the Range Anxiety argument above. It is true that at present there is a lack of public charging points. [Betterplace](http://www.betterplace.com.au) currently has 7 charging points in Canberra although only 6 are listed on their website. Four of these are listed as public and Betterplace intends to roll out battery charging stations as well as more points in the future. Customers also have further access to residential private charging points through their scheme. The battery changing stations are designed to change over the vehicles batteries in less than 5 minutes. They are intended for new vehicles that are compliant with their system such as the Mitsubishi i-MiEV, Renault Fluence and Nissan Leaf.

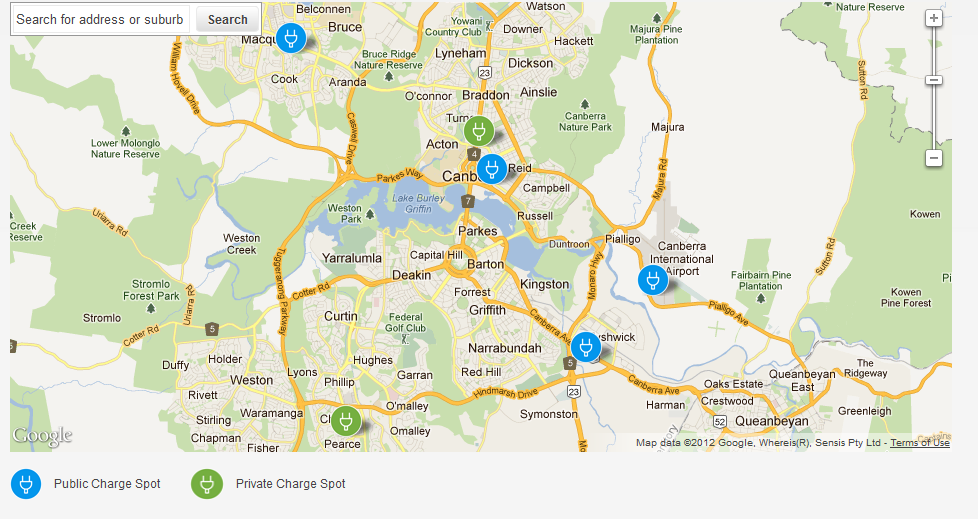


Figure 1. Betterplace charging points in Canberra

[Chargepoint](https://www.chargepoint.net.au) is another supplier of charging points for electric vehicles. They currently have one point listed in Canberra but have a large portion of the market in other parts of New South Wales and Australia.

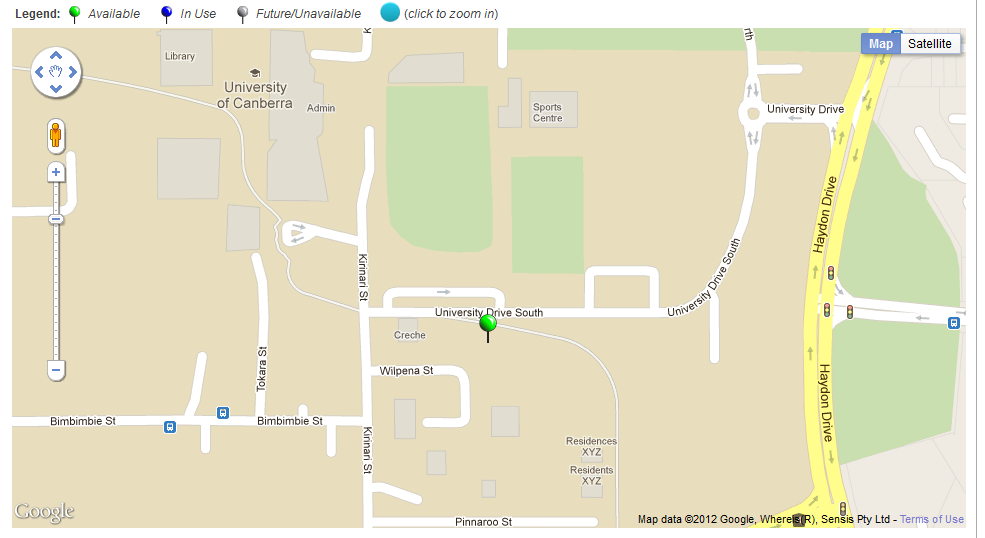


Figure 2. Chargepoint charging point in the University of Canberra

Both of these companies use 15A charging outlets that either comply with the Australian Standards (standard 15A socket outlet with a larger earth pin) or 32A socket outlet that comply with the European Standards (7 pin) or American Standard (5 pin).



Figure 3. Standard Australian 15A socket outlet



Figure 4. Betterplace 32A plug and socket



Figure 5. Chargepoint 32A plug

Concerns raised by the limited amount of EV charging infrastructure are somewhat unfounded as most vehicles being used for everyday commuting would only require charging once or twice a day (at home and at work). This could be accommodated by a standard 15A socket outlet, although the charging companies do offer related services such as state of charge monitoring.

Another argument is that the grid may not be able to cope with the increased demand of EV charging. This might be the case during the day once EV uptake is substantial but most EV will probably be charged over night when power usage is minimal nationally. In a perfect world the 15A socket outlet might even be connected to off peak power.

## Economical and environmental advantages.

Electric vehicle popularity is being driven primarily by environmental concerns (including but not limited to climate change) and economical advantages. Other factors include energy efficiency, air quality (exhaust fumes have proven links to heart and lung diseases and cancer), and oil dependency from unstable countries.

Even connected to “dirty” electricity supplies EV’s have lower CO2emissions due to the increased efficiency and overnight charging time(when electricity is still generated but used less). Whilst solar power is only available during the day, EVs could provide a means of storing any excess electrical energy for later use. Wind turbines typically generate more power in the hours before dawn.

Even connected to “green power” the cost of recharging an EV is substantially less than the cost of refuelling a combustion engine vehicle (and no detour/fill up time at the service station).

He down side is firstly EVs are environmentally and economically more costly to produce, as their production rate is low, and the cost per capita for manufacturing, research and development, marketing and the like is quite high. This cost will come down as the uptake of EVs increases globally (especially in India and China).

Secondly, batteries are manufactured with toxic substances such as lead, lithium and cadmium. Although cadmium is being phased out by nickel metal hydride and lithium, and lead is still a viable cheap alternative, these substances can have a devastating effect if not handled correctly and recycled or cleaned up and correctly disposed of after an accident.

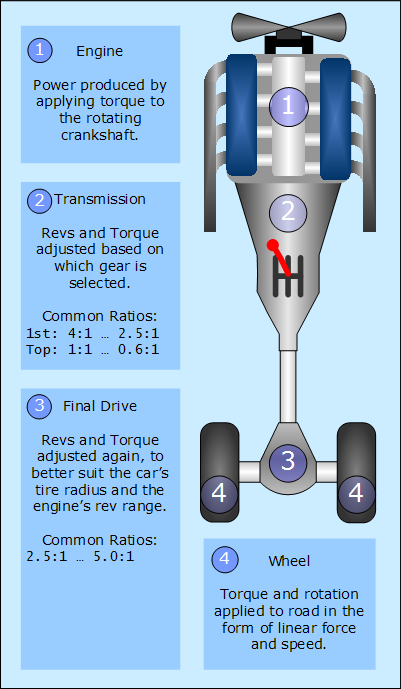
## What type of vehicle can I convert?

Pretty well most vehicles can be converted to electrical but several factors should be considered first:

1. The quality of the vehicle – are the major parts of the vehicle that AREN’T being replaced in good order?
2. Air Bags – vehicles manufactured before 2000 in Australia may not have air bags installed and as a result are easier to modify (but are not as safe in a collision).
3. Manual transmission – manual transmissions are more efficient and easier to connect the electric motor to (although automatics are possible).
4. Weight/Drag – heavier or less aerodynamic vehicles take more energy to move, limiting the range of the vehicle.
5. Battery space and placement – Most cars place the batteries under the floor or in the boot. Utilities are easier as the batteries can be placed under the tray and motorbikes usually locate the batteries between the handlebars and the seat.

# The Task

Firstly consider the car.



<http://craig.backfire.ca/img/drivetrain.png>

After removing the petrol tank and engine (to be covered later) we are left essentially with the gearbox, differential and axle/wheels. The best results would be achieved by attaching the motor (probably 2) directly to the wheels but this adds complications and more costly to engineer.

Basic Combustion Engine Arrangement

Basic Electric Vehicle

In its simplest form an electric vehicle consists of an electric motor, a controller and batteries. The batteries supply regulated power to the motor via the controller. The controller regulates the power to the batteries by varying the output power to the motor. A variable resistor or the like on the accelerator pedal enables the driver to drive as per normal. Some controllers also allow for regenerative braking which charges the batteries whilst slowing the vehicle down.

All of the car’s normal electrical system (minus the engine bits) must be maintained so that they operate in the same manner. D.C. power is sent from the main or drive battery to the auxiliary battery via a D.C. to D.C. converter. As the power steering, power brakes and windscreen demister are all controlled and/or powered from the EV controller it is essential for the safety of the vehicle that the 12V system fail AFTER the main batteries fail.

D.C Auxilliary system

Power steering from the original vehicle is retained as well as the brake power booster. As both systems are hydraulic they will need motors to replace the combustions engines roll. The air conditioning system can also be replaced in this manner.

The Australian Design Rules (ADR) requires that a converted vehicle should also have a front windscreen demister as a substitute for the heat being directed off the combustion engine.

Complete converted electric vehicle.

## OHS and Electrical Safe Working Practices

1. Basic Principles of OHS
2. Workshop OHS management and Hazards of the Work area
3. Required tools and Safe use
4. Electrical Safety, Effects and Emergency Procedures
5. Battery Safety and Emergency Procedures

## Engine Removal

1. Preparation

Probably the most important tool that you can obtain is a service manual for the vehicle concerned. This will not only have procedures and diagrams to assist you in removing the engine but it will also prove useful when maintaining the vehicle in other areas. A service manual will also be insightful in modifying the brake, steering, cooling and auto electrical systems. Service manuals for most makes of vehicles are available in most cap part shops and online. Using an online search engine like google can also deliver manuals for not only the car but also most of the parts (especially if you search for them using the manufacturer name and part number).

A well prepared work area can cut conversion time and injuries down and spirits up. If you ensure that all required tools and equipment are present and in working order, hours of time spent buying new tools can be avoided. If you aren’t familiar with the use of certain equipment seek advice and instruction from an experienced person or better still have them on hand when you are attempting your first few uses.

Have all of the components, with the exception of the batteries, on hand so that planning their location is easier.

1. Required Tools, Labour and Equipment
2. Procedure

Workshop equipment - Automotive mechanical technology

<http://tle.tafevc.com.au/toolbox/items/1daf8c20-372a-8cc5-a0a7-8eef6f62b9ee/1/>

Locate the removal procedure for units and assemblies in a service manual

<http://tle.tafevc.com.au/toolbox/items/1ad764f6-a093-edc2-8c24-96f446f81e6e/1/viewscorm.jsp>

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| Calculate length, perimeter, area and volume  <http://tle.tafevc.com.au/toolbox/items/ee2534dd-e04d-6fac-cdc0-17ea863308f2/1/>  Electrical assemblies  <http://tle.tafevc.com.au/toolbox/items/728cb6dd-8830-107c-bf8d-a1758d4979d6/1/>  Tap off fluid lines on a vehicle  <http://tle.tafevc.com.au/toolbox/items/c2fa958f-ded4-6c7a-6c73-3a2e8238b971/1/>   |  | | --- | |  | | Use equipment to remove and replace mechanical assemblies   |  |  | | --- | --- | | To remove and replacing mechanical units and assemblies you need: spanners, vehicle hoists, floor jacks and lifting gear accessories. | | | Photo of an off-set ring spanner turning a nut/bolt in a recessed confined space | Spanners  There are two types of spanners: open-end and ring or box-end. Choose the correct spanner to do the job and avoid damaging the head of the bolt or nut. Most modern vehicles have either SAE/AF (Standard American Equipment/American Fine) or metric bolts and nut fasteners.  Spanners come in a variety of sizes and styles, with the size of the spanners being determined by the jaw opening. For example, a ¼’ SAE/AF spanner is 4½” long, while a ¾” SAE/AF spanner is 10” - 12” long.  Open-end spanners  The open-end spanner fits both square head (4 corners) and hexagon head (6 corners) nuts. Open-end spanners are often angled 15o to 30o at both ends.  Ring or box-end spanners  The ring spanner comes in a variety of sizes, points and off-sets. Ring spanners are available in 6, 8 or 12 points. The jaws of the spanner fit completely around a nut or bolt, gripping each point of the nut.  Off-set spanners  The handles of many ring spanners are off-set to provide hand clearance. Handles are off-set at 10o-60o, to help you turn a bolt or nut that is recessed or in a confined area. | | Photo of a lifting point  Photo of a lifting point | Vehicle hoists  A hoist is used to raise a vehicle clear of the floor and allows the engine, gearbox, differential or strut to be removed. Always use the manufacturer’s approved lifting points when removing the engine.  Here are some examples of lifting points on two different vehicles. | | http://tle.tafevc.com.au/toolbox/file/53685b63-a269-d682-bd59-90c8f0cd2da6/1/503_aur27064a_tme4_1.zip/panelbeating/AUR27064/AUR27064A_TME/AUR27064_TME4/AUR27064_TME4_RES/AUR27064_TME4_03.jpg | There are many hoists available - the most common having two lift points - one on each side of the vehicle.  Each post is fitted with a lifting bar with two arms attached. Each arm has a sliding extension with a swivel pad attached. These are positioned under the vehicle lift points. Consult lubrication and servicing guides before lifting an unknown vehicle model. | | Photo of the control section of a two post hoist | Vehicle hoist control panel  The vehicle hoist will have a control panel consisting of an Up switch, a Down switch and an Emergency Stop | | http://tle.tafevc.com.au/toolbox/file/53685b63-a269-d682-bd59-90c8f0cd2da6/1/503_aur27064a_tme4_1.zip/panelbeating/AUR27064/AUR27064A_TME/AUR27064_TME4/AUR27064_TME4_RES/AUR27064_TME4_05.jpg | Using a two-post hoist  Before operating any hoist, ensure you know the safety requirements and the operating technique. Make sure the hoist is fully down and the extension arms and swivel pads will not damage the under-body. Next, drive the vehicle into a central position. Leave the transmission in neutral and the parking brake off. Close vehicle doors and lower or remove radio antenna.  Next, position the hoist swivel pads under the vehicle lift points and check the manufacturer’s guide for the location of the swivel pads. Check that the hoist will not contact or crush any under-body fittings when the pads make contact with the vehicle. Check there is enough clearance above the vehicle to prevent damage to air, power or light fittings when raised.  Now, press the Up button. Release the Up button when the swivel pads make contact with the vehicle. Recheck the under-body components for clearance. Recheck the position of the swivel pads to ensure no under-body damage can occur and that the vehicle is central on the hoist.  Finally, release the Up button when the working height is reached. Make sure the safety system is engaged and operating before you move under the hoist.  To lower the vehicle you must ensure the vehicle doors are closed and the under-hoist area is clear of obstructions. Then, release the safety system and press the Down button so the hoist starts descending. After the hoist is fully down, fold back the swivel pads and arms to clear the vehicle under-body. Slowly drive the vehicle off the hoist, and listen for any under-body contact.  A hoists should never be used when it is jerky when raised, lowers itself from a raised position, rises slowly when in use, lowers very slowly or leaks oil from any seal or hose. If you observe any of these faults, follow workplace procedures to notify your supervisor. | | Photo of a four-wheel floor jack with jack lifting saddle in up position | Floor jacks  Floor jacks come in many sizes and lift capacities. The maximum lift capacity is listed on a decal (sticker) attached to the jack.  Operating a floor jack.  To raise the vehicle, place the jack lifting saddle under a vehicle component capable of withstanding the load. Pump the handle until it reaches the required height. To lower, twist the handle counter-clockwise. | | Photo of a floor jack raising a vehicle at the front | Jacking points are where the jack is applied to lift a wheel/s off the ground. Consult the owner’s handbook or the vehicle service manual for the correct vehicle lifting positions. Small vehicles have a jacking point each side, while heavier vehicles normally have two points at each side. | | Photo of a safety stand supporting the rear | Do not remove wheels or work under a vehicle while it is on a hydraulic jack. Support the vehicle with steel safety stands before the work commences. The point of contact must not be angled or of a shape that will allow the stand to slip. | | Photo of an engine being lifted by a chain sling (including lifting hook) | Lifting gear accessories  When removing an engine from a vehicle, you may require hooks, chain or sling, and eye bolts or shackles.  The angle of the sling is important. The maximum recommended angle between the slings is 90o. If the angle is substantially increased, each sling would carry a load equal to the weight of the engine.  Never bend the sling around sharp corners and edges or twist or kink the sling. Never use a worn or damaged sling and always observe the Safe Working Load (SWL). Always position slings or chains correctly and stand well clear of the load. |     <http://tle.tafevc.com.au/toolbox/items/53685b63-a269-d682-bd59-90c8f0cd2da6/1/> | |
| Remove a mechanical unit   |  |  | | --- | --- | | Removing the engine and gearbox  The engine-gearbox assembly may have to be removed in order to carry out the necessary body repairs.  Protective clothing  Always wear protective clothing, ie: overalls and safety footwear, when removing an engine. Safety glasses must be worn when doing some of the operations.  To store parts securely, you need to identify all the parts as they are removed. Then, clearly label these parts, and tag and label all bolts and parts. | | | Photo of bonnet hinges marked for removal | Here are the steps to remove and replace mechanical units   1. Remove the bonnet. Hinges may be marked with a pencil or tape. | | Photo of fuel lines labelled before they are pulled apart | 1. Disconnect the fuel tank line from the fuel rail. If necessary, depressurise the fuel line before it is disconnected. 2. Remove top and bottom radiator hoses from the motor. Drain the coolant before you start. 3. Disconnect adjacent wires, harness and pipes. Identify all parts correctly. | | http://tle.tafevc.com.au/toolbox/file/ea8da20c-2a30-66aa-0069-f2ce074231ef/1/503_aur27064a_tme5_1.zip/panelbeating/AUR27064/AUR27064A_TME/AUR27064_TME5/AUR27064_TME5_RES/AUR27064_TME5_01.jpg | 1. If practicable remove the air-conditioner by undoing the securing bolt. This means the air-conditioning system will not have to be decommissioned. 2. If necessary remove the drive belt that connects the alternator to the air-conditioner compressor to allow the engine assembly to clear the air-conditioner compressor 3. Remove the front exhaust pipe from the manifold. Follow procedures for removing these components. 4. Remove the power steering pump from the engine assembly, if necessary, to allow the engine to move backwards in such a way that it misses the air compressor when the motor is lowered to the ground. 5. Disconnect the throttle cable and mark where it connects to the engine. 6. Disconnect the gearshift selector from the automatic transmission. 7. Jack up the front of the vehicle. Chock wheels and place safety stands. 8. Remove the bolts holding the engine mounts to the upper body of the vehicle, using a portable engine lifting hoist if necessary. | | http://tle.tafevc.com.au/toolbox/file/ea8da20c-2a30-66aa-0069-f2ce074231ef/1/503_aur27064a_tme5_1.zip/panelbeating/AUR27064/AUR27064A_TME/AUR27064_TME5/AUR27064_TME5_RES/AUR27064_TME5_02.jpg | 1. Remove the right and left hand steering tie-rod ball joints from the steering arm, using the tool recommended in the workshop repair manual. | | Photo of the brake lines being disconnected | 1. Disconnect the brake lines on both struts, using the correct brake line spanner. | | Photo of undoing retaining nuts which hold the front suspension struts to the inner skirts | 1. Undo the retaining nuts holding the front suspension struts to the inner skirts. | | Photo of bolts being removed from the engine support cross member | 1. Support the engine with the portable hoist and holding equipment, then remove the 4 bolts holding the engine support cross member. Use the workshop repair manual to identify the correct mounting spots. 2. Lower the engine. 3. Tag and store the engine. | | Use the reverse sequence to replace the engine.  When you replace the engine, remember to bleed the brakes and check that all the electricals are working. You also need to replace the radiator coolant and make sure the engine is running smoothly. | |   <http://tle.tafevc.com.au/toolbox/items/ea8da20c-2a30-66aa-0069-f2ce074231ef/1/>  Undertaking diagnostic procedures  <http://tle.tafevc.com.au/toolbox/items/8748240a-b698-1856-bf65-1ec9e6831ce8/1/>  Liquid waste management - Automotive mechanical technology  <http://tle.tafevc.com.au/toolbox/items/ff9cc188-07e6-cb12-5751-3c50ddd83641/1/> |